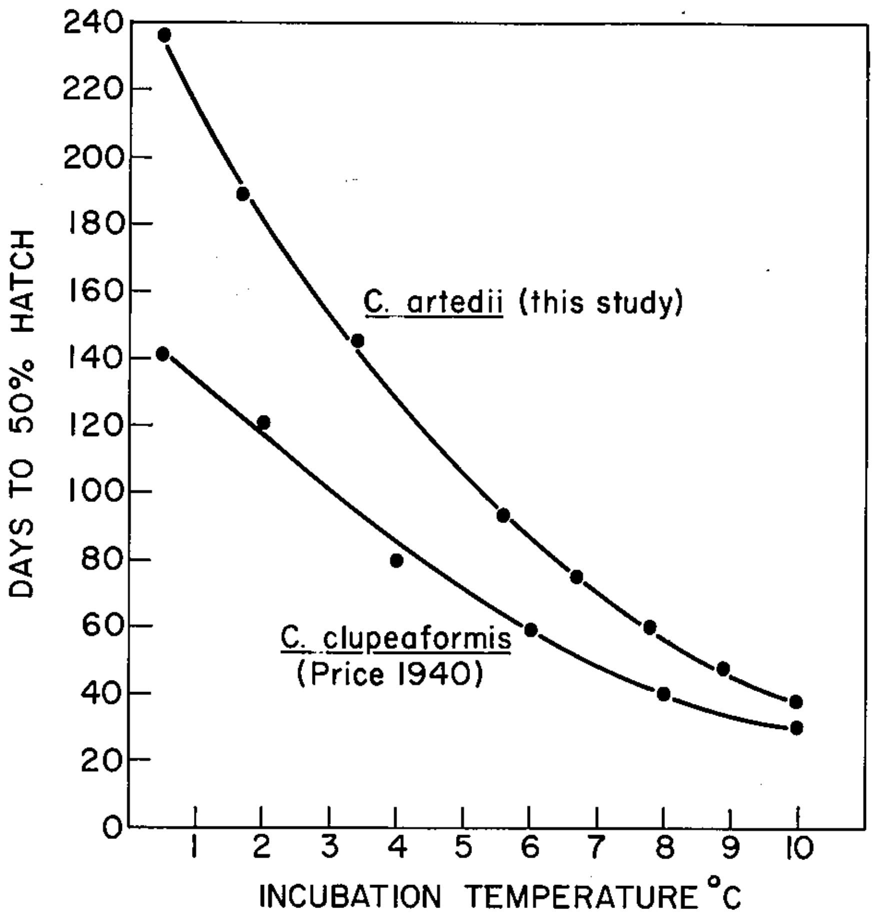

Fig. 7. Duration of incubation for lake herring and whitefish eggs incubated at various temperatures.

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EARLY SCALE DEVELOPMENT ON THE GREAT LAKES COREGONIDS, COREGONUS ARTEDII AND C. KIYI [a]

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ABSTRACT

Hatchery raised Coregonus artedii and C. kiyi from 17.8 to 94.7 mm total length were examined. Scales were removed from between the anal fin and lateral line. Scale diameters were measured and the pattern of scale development was noted for all samples. The first scales appeared on C. artedii along the lateral line above the anal fin, when the fish were 34.0 mm long. Dorsal scales appeared when C. artedii had reached a length of 37.0 mm. C. kiyi had dorsal and anal scales at a total length of 32.2 mm. C. artedii was completely scaled at 55.0 mm and C. kiyi at 51.0 mm The last areas to become completely scaled for both species were between the pectoral fins and just posterior to the supraoccipital. The significance of a body-scale relationship described by two straight lines is discussed.

INTRODUCTION

Early scale development has been described for several species on North American fishes exclusive of the genus Coregonus; the flier, Centrarchus macropterus, by Conley and Witt (1966); the northern pike, Esox lucius, by Franklin and Smith (1960); the black crappie, Pomoxis nigromaculatus, by Ward and Leonard (1952); the white crappie, Pomoxis annularis, by Siefert (1965); the freshwater drum, Aplodinotus grunniens, by Priegel (1966); and the walleye, Stizostedion vitreum, by Priegel (1964). Fish (1932) reported on larval and juvenile stages of Great Lakes fishes, including C. artedii and the lake whitefish, C. clupeaformis, but lengths at scale formation or pattern of scale development were not described.

Coregonids have represented a major economic resource to the Great Lakes fisheries for many years (Baldwin and Saalfeld, 1962), and because of this, numerous life history studies have been made (Van Oosten, 1957; Hile, 1966). Little has been published on the fry of this group in North America because they are difficult to capture (Wells, 1966; Fish, 1932; Hart, 1930), and the major emphasis has been on fish of commercial size.

The fish used in this study were reared at the Bureau of Commercial Fisheries hatchery in Northville, Michigan, and they

[a] Contribution No. 33, Center for Great Lakes Studies, Univ. Wis.-Milwaukee, Milwaukee, Wisconsin.

were from parents of Lake Superior origin. A detailed account of the hatchery operations and scale growth of several species of coregonids has been made (Hogman, 1968).

METHODS

Preserved lake herring, C. artedii, and kiyi, C. kiyi, 17.8 to 94.7 mm total length were used. Fish were swabbed with an alizarin red solution, examined and measured with a binocular microscope, and three to seven scales were removed from two locations. The scales were taken midway between the lateral line and dorsal fin, and from just under the lateral line directly above the anal fin. Samples from these two locations will be referred to as dorsal and anal scales, respectively. The scales were mounted between glass microscope slides and the greatest anterior-posterior diameter of at least 3 scales from each location was measured on a micro-projector at 41X. A correction factor of 1.023 was used to adjust for shrinkage of fish length due to formalin preservation (Hogman, 1968).

SCALE DEVELOPMENT

The smallest specimen of lake herring that had scales above the anal fin (anal scales) was 34.0 mm total length. The smallest kiyi with anal scales was 32.2 mm. On both species the earliest indication of scale papillae appeared just anterior to the caudal peduncle adjacent to the lateral line. Twenty-two lake herring from 17.8 to 31.2 mm were examined, and all were without scales. Scales were not present on 16 kiyi from 19.5 to 27.3 mm total length.

Measurements of scale diameters suggest a possible earlier formation of scales in kiyi than in herring. The magnified diameters of anal scales for the two smallest lake herring (35.0, 35.5 mm) were 4.1 and 3.8 mm, whereas for kiyi (32.2, 35.9 mm) the scales were 7.0 and 8.0 mm (Table 1). The lake herring formed anal scales earlier than dorsal scales and the smallest kiyi with scales had both anal and dorsal scales. It is likely, therefore, that kiyi formed anal scales between 27.3 and 32.2 mm total length.

The horizontal scale rows that formed initially above the posterior end of the anal fin extended anteriorly and posteriorly in fish larger than 34 mm. Concurrently, additional horizontal scale rows formed on both sides of the lateral line above the anal fin.

The smallest lake herring from which scales could be taken between the lateral line and dorsal fin (dorsal scales) was 37.0 mm, and from the kiyi, 32.2 mm (Table 1). At this fish size the anal scales were approximately twice the diameter of the dorsal scales, were transparent, and had no circuli. At these lengths the caudal peduncle of each species was completely covered with scales.

Scalation progressed anteriorly, and the smallest scales at the margin of the scaled area formed an arc that swept posteriorly above and below the lateral line, much as described for the white crappie (Siefert, 1965), and the freshwater drum (Priegel, 1966). The last areas to become completely scaled for the lake herring and

TABLE 1. Relation between total length and diameter of scales between the dorsal fin and lateral line (dorsal scales) and between the anal fin and lateral line (anal scales) of lake herring and kiyi. Scale sizes are at 41 X.

LAKE HERRING		
Total Length (1) (mm)	Dorsal Scale (2) dia.(mm)	Anal Scale dia.(mm)
34.0	0	4.1
35.5	0	2.8
36.1	0	5.3
37.0	3.7	9.4
37.6	7.4	9.4
37.9	6.1	9.8
38.3	4.1	8.2
38.3	6.1	9.4
38.7	9.0	8.2
39.1	5.3	11.5
39.3	10.0	8.8
39.7	9.4	15.6
39.9	7.4	12.3
40.0	13.5	17.5
40.2	13.1	18.9
40.3	10.7	14.0
41.0	13.5	17.0
42.3	17.0	22.2
43.1	17.2	22.0
43.5	17.2	21.0
44.6	22.0	25.0
44.9	22.0	22.0
45.0	18.5	24.0
45.7	17.6	19.6
46.0	21.7	26.1
46.5	19.2	21.3
50.4	25.8	27.9
51.4	27.0	28.7
51.4	28.4	30.9
52.5	29.0	36.0
52.6	28.8	32.4
54.0	27.3	33.6
55.0	33.2	37.1
61.0	34.0	44.2
63.5	45.0	52.3
73.0	46.0	56.3
84.0	61.0	75.1
86.2	51.1	69.3
94.7	64.3	71.2

Table 1, continued.

KIYI		
32.2	3.0	7.0
35.9	3.7	8.0
36.1	2.1	11.7
37.3	0	7.0
37.7	10.2	13.5
42.8	17.0	22.5
43.0	16.0	13.5
46.0	19.8	21.0
49.1	24.0	28.0
49.7	18.3	26.4
51.0	26.1	29.5
53.6	33.0	37.0
59.0	41.1	44.6
71.5	45.4	51.8
72.0	46.0	50.2
76.0	49.4	57.7

(1)Twenty-two lake herring under 34.0 mm total length and sixteen kiyi under 32.2 mm had no scales and are not included in this table.

(2)All scale measurements are for the average of at least three scales.

kiyi were between the pectoral fins and just posterior to the supraoccipital. These areas were completely scaled on lake herring longer than 55.0 mm and on kiyi longer than 51.0 mm. Fish (1932) described a completely scaled lake whitefish of 83.0 mm, and Hart (1930) described lake whitefish of 34.2 mm as without scales, with scale papillae appearing at 45.4 mm and complete scalation at 54.0 mm. Pritchard (1930) did not find scales on lake herring to 20.0 mm total length. Hagen (this volume) found that the mountain whitefish, Prosopium williamsoni, was fully scaled at a fork length of 40.0 mm. Koelz (1927) did not have specimens to describe early scale formation, and Hankinson (1914) did not describe scalation on his young whitefish (later identified by Koelz as probably young lake herring, Van Oosten, 1928, p. 348).

The evidence of size of fish at first anal scales, first dorsal scales, and complete scalation, suggests that kiyi were one to four millimeters shorter at the equivalent stage of scale development than lake herring.

BODY-SCALE RELATIONSHIP

The plot of fish length and magnified scale size (dorsal) of lake herring and kiyi did not show a straight line relationship (Fig. 1). For lake herring and kiyi, two relationships for each were apparent and both species had the same type body-scale relationship. Two straight lines described this relationship for each

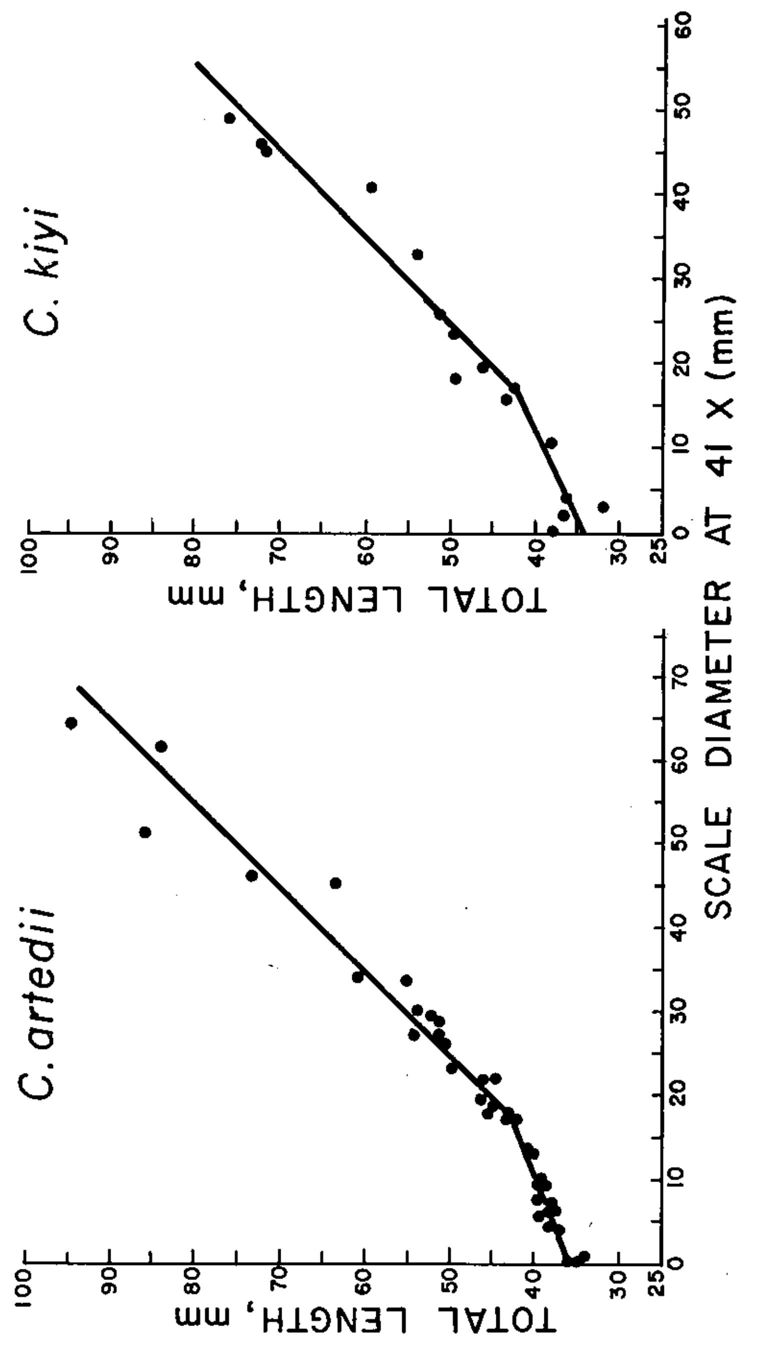

Fig. 1. Body-scale relationship of C. artedii and C. kiyi using dorsal scale diameters (41X) only. The first circulus formed on the scales near the point of slope change.

species. The first line for lake herring started at a total length of 36.5 mm and continued with slope 0.40 until 43.5 mm. The second half (also a straight line) started at a total length of 43.5 mm and continued with slope 0.89. The total length of 43.5 mm corresponded to a magnified scale size of 17.5 mm. Two nearly identical lines were found for kiyi, but the data did not permit accurate determination of the intercept or slopes. Brown (1960) found a similar body-scale relationship in small mouth bass, Micropterus dolomieui, and rock bass, Ambloplites rupestris. Chapoton's (1967) graph of the gulf menhaden, Brevoortia patronus, shows the same relationship if the best line is drawn for the smallest fish.

Using all of the data to construct a single regression line would yield an intercept on the total length axis of lake herring of approximately 31 mm, 5.5 mm less than using two lines. Using data from fish 44 mm to 94 mm only would give an intercept close to 26 mm. Thus either of these methods would not provide reliable information about fish size at first scale formation in the absence of specimens that included fish with no scales.

The initial short segment (probably curved upward somewhat) of the body-scale relationship, followed by a straight line, indicates rapid growth of the scales followed by proportional growth of body and scales. Imbrication is followed by centripetal pressure on the scale periphery causing circuli to form. The circuli indicate partial retardation of scale growth. The first circulus was noticed on dorsal scales with a diameter between 16 and 20 mm (magnified), and coincides with the scale size when the second straight line relationship began. Fish 45 to 55 mm long with scales below the dorsal fin 20 to 35 mm in magnified diameter had 2 to 6 circuli.

The intercepts obtained by the method described in this paper do not affect calculations of growth from scales. The only reliable intercept for calculation of growth must come from scale samples taken just before the first annulus has formed through the largest individuals, not from intercepts derived from scales of fish below the length at first annulus formation as suggested by Priegel (1966) and Chapoton (1967). For hatchery raised lake herring and kiyi (fish that were hatched with specimens used in this paper but allowed to live to larger sizes) I have shown the regression equations to be $Y = 40.7 + 0.934 X$ (intercept 40.7 mm) (Hogman, 1965), and $Y = 34 + 0.947 X$ for kiyi (Hogman, 1968).

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ECOLOGY OF YOUNG LAKE WHITEFISH (COREGONUS CLUPEAFORMIS) IN SOUTH BAY, MANITOULIN ISLAND, LAKE HURON[a]

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ABSTRACT

Young-of-year whitefish from a population restricted to South Bay, Lake Huron were sampled with small otter trawls during 1965-1969. Depth distribution, spatial distribution, growth, feeding habits, co-inhabitants and annual variations in abundance are described. The trout-perch (Percopsis omiscomaycus) was the most abundant co-inhabitant and greatest potential competitor within the restricted zone in the metalimnion in which young whitefish were found during the months of July and August. Significant differences in growth of young whitefish were detected between years. A marked reduction in growth rate occurred near the end of August. Penetration by the fish from the metalimnion into the hypolimnion at this time was the probable direct cause of change in growth rate but the mechanisms triggering the change in depth, temperature, light, etc., preferences are obscure. A partial check becomes apparent on the fish scales approximately a month and a half after this descent into the hypolimnion and the reduction in growth. The food habits of the fish slowly increase in scope during the first year. The diet changes from primarily plankton to principally benthic organisms. Differences in kinds and size of food organisms consumed by adult and young whitefish, in addition to differences in depth distribution, reduce intraspecific competition between these age groups.

INTRODUCTION

Although lake whitefish (Coregonus clupeaformis) have long formed an important part in the economies of people in the Nearctic region (Koelz, 1929), little has been accomplished in understanding how the resource renews itself in the face of intensive exploitation. Most notably, Hart (1930) studied the spawning, egg survival and early life history of this species in the Bay of Quinte region of Lake Ontario. Price (1934a, 1934b, 1935, 1940) studied the embryology of whitefish and effects of different incubation temperatures on the rate of development and survival. Wickliff (1933) estimated the mortality of whitefish eggs artificially spawned at different

[a]Contribution of the Ontario Department of Lands and Forests, Research Branch, Maple, Ontario.

BIOLOGY OF COREGONID FISHES

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